# Performance of ETC Controller in High Volume Production

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## ABSTRACT

As chipmakers continue to reduce feature sizes and shrink CDs on the wafer to meet customer needs, Cymer continues developing light sources that enable advanced lithography, and introducing innovations to improve productivity, wafer yield, and cost of ownership. In particular, the ETC controller provides improved spectral bandwidth and wavelength stability, which enables superior CD control and wafer yield for the chipmaker. This controller is a key technology in Cymer's XLR 700ix and DynaPulse™ products. Last year we reported that the XLR 600ix incorporates new controller technology called ETC for improvements in spectral bandwidth and wavelength stability. The Authors will present metrics demonstrating the performance and stability of systems that have been installed at chipmaker sites over the last year.

## 1. INTRODUCTION

Double-patterning ArF immersion lithography continues to advance the patterning resolution and overlay requirements and has enabled the continuation of semiconductor bit scaling. Over the years, Lithography Engineers continue to focus on CD control, overlay and process capability to meet current node requirements for yield and device performance. Reducing or eliminating variability in any process will have significant impact, but the sources of variability in any lithography process are many. The goal from the light source manufacturer is to further enable capability and reduce variation through a number of parameters. Table 1 summarizes the lithography parameter and the light source requirement. [1,2,3,4.]

Table 1

| Litho parameters | Light source requirements |
|---|---|
| Contrast, CD Control | Bandwidth control & stability |
| Dose Control | Energy control & stability |
| Focus, Overlay | Wavelength control & stability |

## 2. WHAT IS ETC?

ETC is a collection of new algorithms for XLR light sources that execute in real time to tightly control the system's central wavelength, and spectral bandwidth. These algorithms comprise linear and nonlinear elements, adaptive feedback and feed-forward, multivariable architectures, and specialized knowledge bases earned through Cymer's years of light source research and development[5]. ETC technology is included standard with Cymer's XLR 700ix and DynaPulse products.

Figure 1 is a diagram of the XLR 700ix system highlighting the location of the line-narrowing module (LNM), the master oscillator (MO) and power ring amplifier (PRA), the pulse power modules and new software which are used to enable algorithms in the light source. There are no changes in the current hardware design of the XLR light source to enable these improvements.

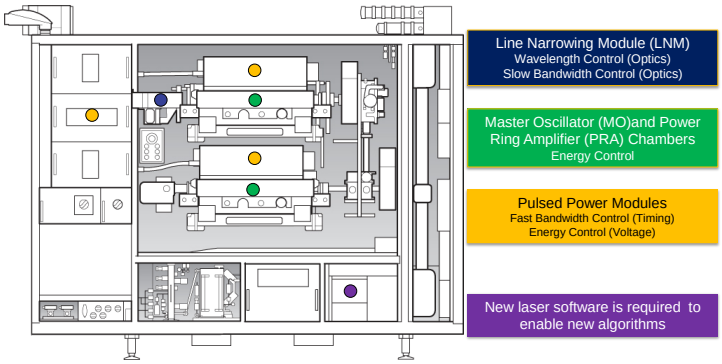


Figure 1

## 3. RESULTS & DISCUSSION

### 3.1 Bandwidth stability

Last year, Cymer demonstrated that with the ETC controller, that bandwidth stability was dramatically improved over the previous generation of XLR, due to the ability of ETC to control the spectral bandwidth pulse by pulse. When ETC is enabled on an XLR system, the controller is able to maintain the bandwidth mean to within ± 5fm of the target as shown in Figure 2. The left side of the plot is legacy controller bandwidth performance, which clearly illustrates the dramatic improvement in performance. Reduction of bandwidth variability has been recently shown to reduce the impact of light source performance on contrast sensitive structures[6], and for 10nm node structures[7] which highlights the importance of this performance improvement.

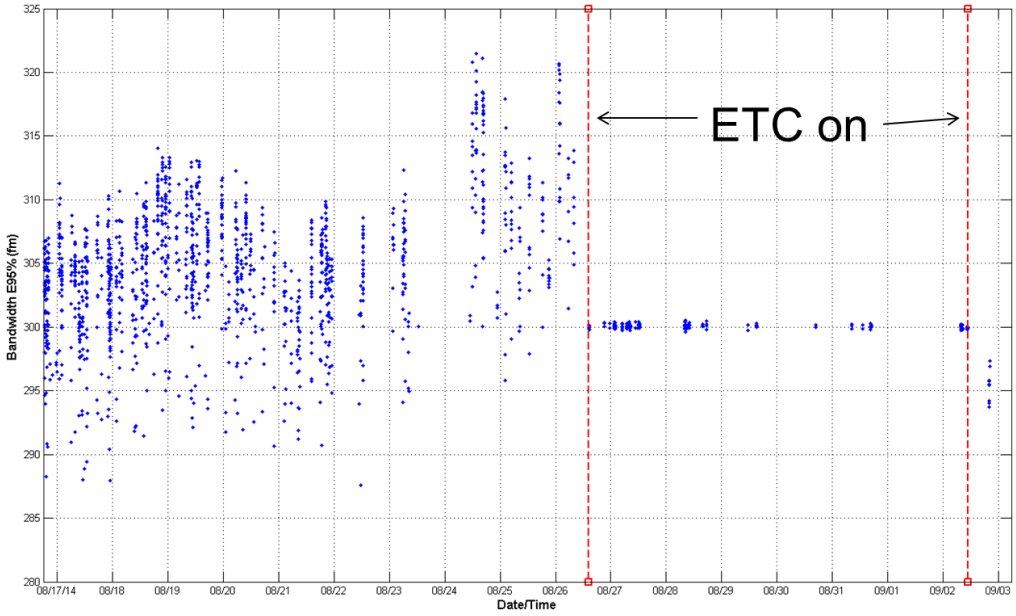


Figure 2 – Reduced wafer to wafer variability enables improved CD uniformity

Throughout the year, chipmakers have continued to receive XLR systems including ETC technology and have placed them into production. Figure **3** shows a histograms of data collected using Cymer's SmartPulse product which has the capability of correlating laser data to wafers. Wafer to wafer bandwidth variability over more than 220k wafers is < ±3 fm from the setpoint (mean ± 3σ), and field to field variability is < ± 10 fm.

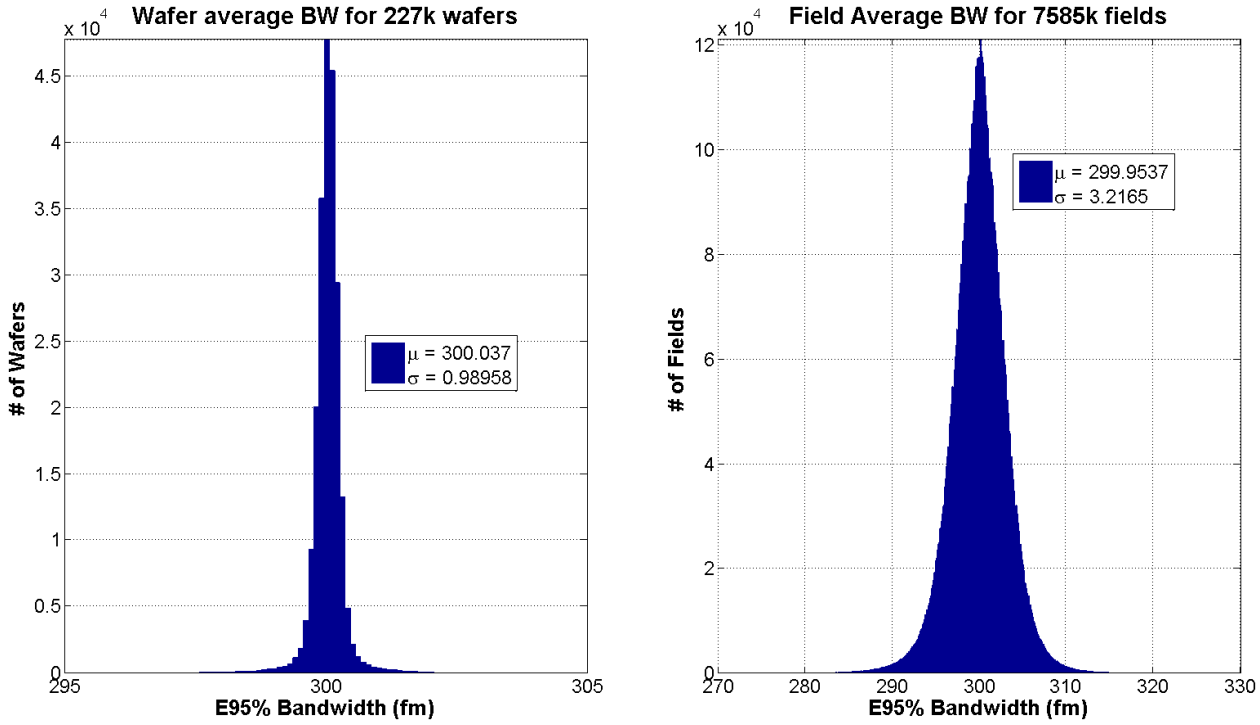


Figure 3 – Bandwidth control over ~220k wafers from systems currently in production. Left plot is wafer to wafer variability, right plot is field to field variability

Cymer also performs simulated wafer exposure test on every XLR system manufactured. Figure 4 shows the performance of >40 systems tested new in Cymer San Diego factory. This is comparable to the performance sampled from chipmaker production, highlighting the stability of the product as it transfers from the Cymer factory into production at chipmaker sites.

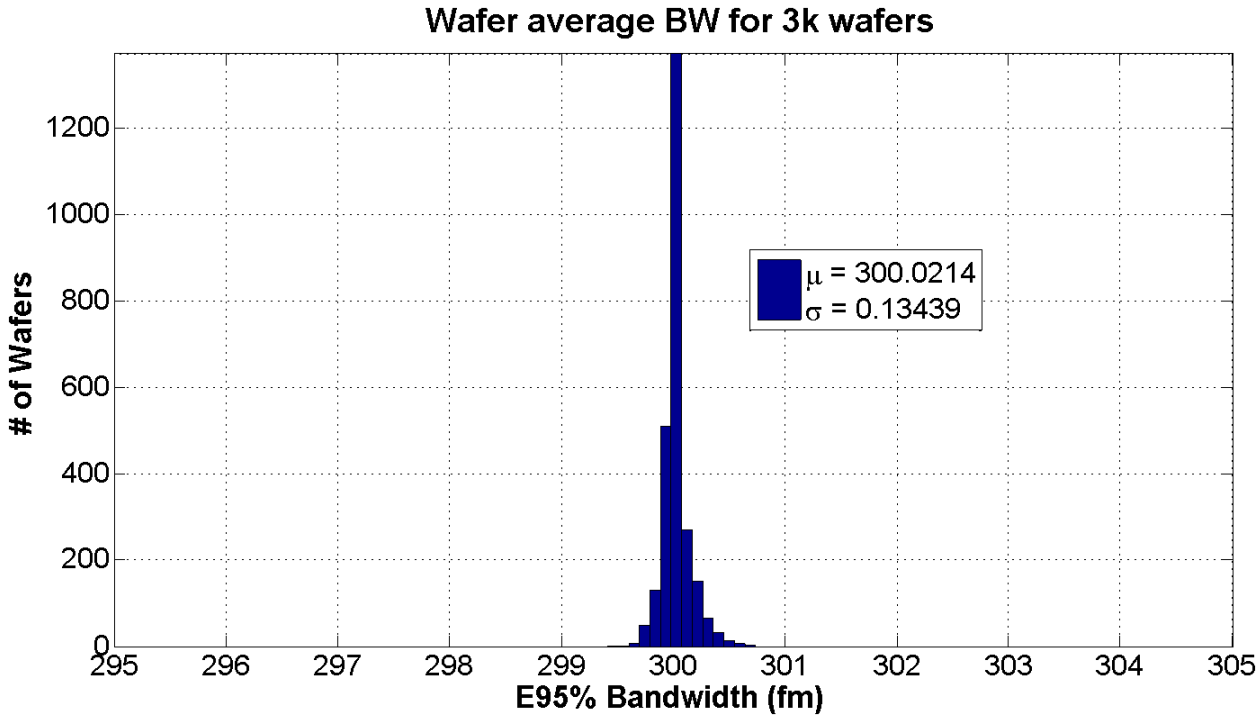


Figure 4 – Wafer to wafer variability for simulated wafers run in Cymer factory production

### 3.2 Wavelength stability

Scanner stage speeds continue to increase to support the higher throughput demands of chipmakers. Scanner focus and overlay requirements are tightening. To the light source, a higher stage speed corresponds to fewer pulses which can be used for control purposes as the imaging slit passes across the exposure field, and tighter focus and overlay requirements imply the light source wavelength stability needs to be tighter. As discussed last year, Cymer has introduced a new wavelength controller with the ETC which improves wavelength stability performance even with >25% reduction in the number of pulses averaged by the slit, as shown in Figure 5[6].

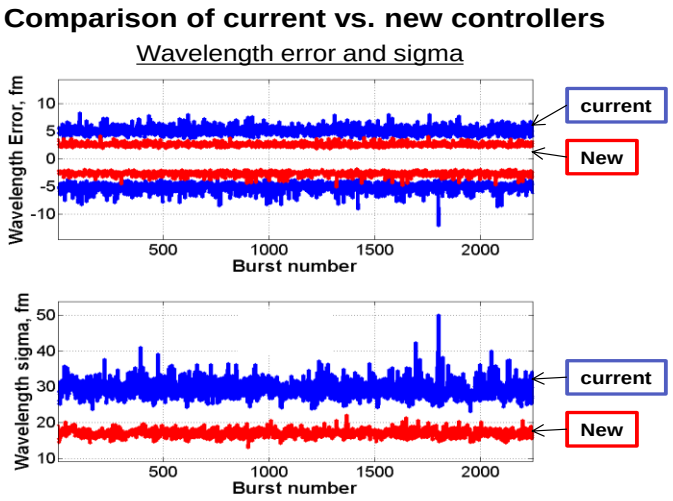


Figure 5 – Demonstration of improvement achieved by new wavelength controller

As stated earlier, chipmakers have continued to put XLR systems including the ETC controller into production, and wafer correlated data is available using Cymer's SmartPulse product. Data from each wafer which records the **worst** wavelength error window per wafer is shown in Figure 6. This data highlights that with the new wavelength controller, that the laser wavelength error is typically < ±8 fm from target for **all fields** in the wafer.

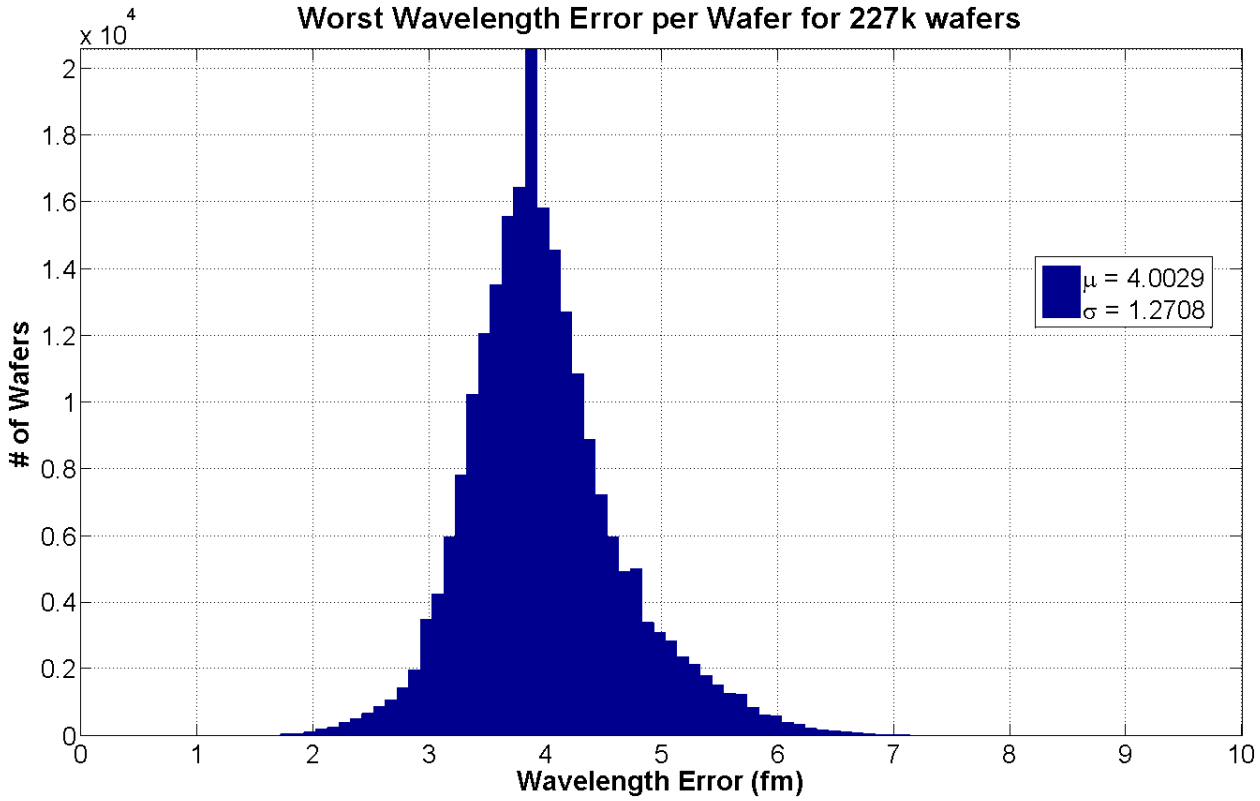

Figure 6 – Worst wavelength error per wafer for >220k production wafers

Once again, examining the simulated wafer exposure data collected during light source manufacturing (Figure 7), the wavelength performance is comparable between the Cymer San Diego factory and in production at chipmakers. This again highlights the stability of the light source after it is installed in customer fabs.

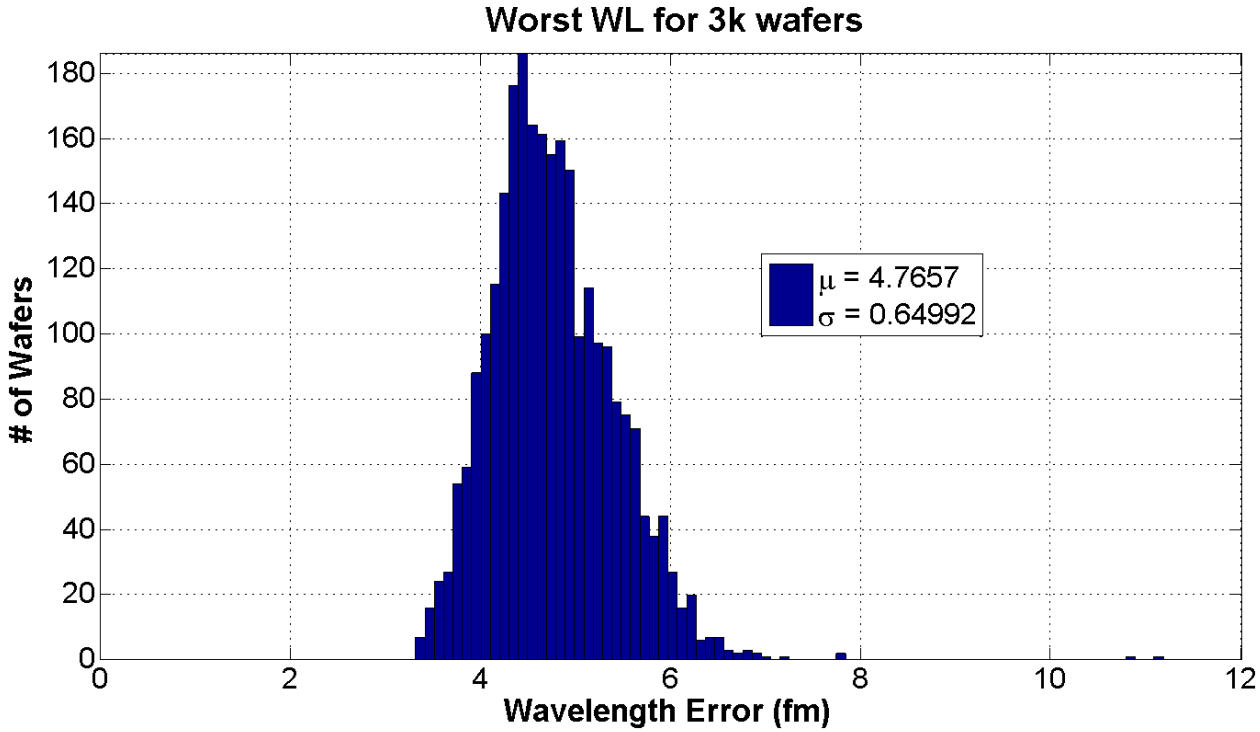

Figure 7 – Worst wavelength window per wafer for simulated wafers run in Cymer factory production

## 4 CONCLUSIONS

In this paper, the Authors have demonstrated the field performance of the previously reported ETC technology for improvements in spectral bandwidth stability and wavelength stability. We have demonstrated performance over a large sample of wafers, from systems in production at chipmakers. Typical performance for the technology is wafer to wafer variability of less than $< \pm 3$ fm from the 300 fm bandwidth setpoint (mean $\pm 3\sigma$). This performance will translate into improved CD control and higher wafer yields. ETC algorithms have been deployed on next generation scanners and are also offered as upgrades for installed systems.

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